# EFFECT OF AIR POLLUTION ON HEALTH

## Report of the Committee on Public Health Relations of the New York Academy of Medicine.

This report on the effect of air pollution on health is the outcome of a request made to the New York Academy of Medicine by Doctor Shirley W. Wynne, Commissioner of Health of New York City, asking that a committee be formed to study and report on the effect of air pollution on health. The report and conclusions are based upon a careful study of the literature of air pollution and its effect upon health; on correspondence and conferences with physicians and engineers (authorities on air pollution), and finally on the opinions of the members of the committee.

Since a bibliography of smoke and smoke prevention, collected by Elwood H. McClelland, has been published by the University of Pittsburgh, only a few references to the literature are included in this brief report.

*Introduction.*

Although the nuisance of smoke is present wherever fuel, rubbish, and gasoline are burned; although everyone abhors smoke, and 25 cities in the United States of more than 30,000 inhabitants have smoke ordinances, these ordinances are not strictly enforced because public opinion has not been sufficiently aroused to demand their enforcement. It was almost a hundred years after Ramazzini published his book on the effect of smoke on health before Laennec and others insisted on the importance of air pollution. The world is indebted to Traube for proving in 1860 that carbon in the air left its traces in the lungs, pleura, and glands of those who breathe such air.

The Mellon Institute of Industrial Research in Pitts-

burgh, under the able direction of H. B. Meller, instituted researches on air pollution in 1912. It is encouraging that similar work is now being carried on in several institutions and with the awakening of public interest and the support of scientific data proving the danger to health and the damage to property caused by air pollution, great improvement will soon be noticed in many cities of the United States.

## Outline of Air Pollution Problem

*Composition of Smoke and Soot.*

Smoke is composed of soot (solid carbon particles resulting from incomplete combustion) and certain volatile gases—sulphuric oxid, carbon monoxid, carbon dioxid, sodium chloride, sulphuric acid, and nitrogen, sulphur, and arsenic compounds.

*Sources of Smoke and Soot.*

Locomotives, chimneys, boats and automobiles are the chief sources of smoke. A committee of the Academy of Medicine has studied and reported on carbon monoxid poisoning and the automobile exhaust (Carbon Monoxid Poisoning and the Automobile Exhaust, *Bull. N. Y. A. M.*, Aug., 1926, pp. 402-440).

*Instruments for Investigations.*

Several instruments and methods for determining the amount and type of air pollution are available.

*Results of Investigation of Smoke.*

An investigation conducted by the Mellon Institute of Pittsburgh in 1924 found the average deposit from smoke in that city to be 89.7 tons per square mile in one month. Records of the Weather Bureau in New York City for 1930 show that the deposit averaged 3.97 tons per square mile per month.

In Pittsburgh the amount of tar has decreased materially since 1913 while the combustibles other than tar and

ash have increased. The increase in solid matter deposited is due partly to an increase in the number of stacks, but principally to the fact that legislation has attempted to control only dense smoke which is possibly not as serious a menace to health as transparent poisonous smoke. It is hoped that further investigations of the poisonous effects of smoke may be made in New York City.

## Substances Which Pollute the Air

1. *Sulphur.* Sulphur is present in smoke in the form of $SO_2$ (sulphur dioxid) and $H_2SO_4$ (sulphuric acid). It has been estimated that in London almost 50 tons of sulphur are poured into the air each day. In Glasgow and Manchester, it is stated, 20 tons escape each day in the smoke. According to Rideal, the quantity of sulphur present in the air of London, from different analyses, is from 0.15-0.77 grams per 100 cubic feet. At Kew, as much as 2% of sulphur was found in an analysis of dust from an exposed surface. According to Nicholson, one-half cwt. of sulphuric acid is deposited over every square mile of Manchester, and in Chelsea much more is deposited.

It is probable that sulphurous fumes are the most deadly of all the gaseous constituents of smoke. In this connection Evans states: "Sulphur compounds are very objectionable and probably more harmful than carbon compounds. Probably before long our dense smoke ordinances will be changed so as to add to the carbon control other provisions which will control sulphur compounds. Possibly, also, the combustion experiments will likewise be directed more to the solution of the sulphur problem."

Schaefer, who has made a special study of the effects of sulphur gases on health, attributes lasting and serious results to the inhalation of these gases. Sulphur fumes, he believes, play a large rôle in the etiology of asthma.

Ascher has cited experimental work done by Kimball on rabbits which demonstrated the fact that, by causing rabbits to breathe small quantities of sulphuric acid fumes the

number of tuberculous infections were increased. He also states that other experimental work has shown that sulphur inhalation causes a decrease in the bactericidal action in tuberculous lungs and a lowering of the power of resistance.

2. *Arsenic.* Most varieties of coal contain small quantities of arsenic. According to Cohen and Ruston arsenic found in air and water is derived from coal smoke.

3. *Carbon monoxid.* Carbon monoxid is a product of combustion. The smoke from iron furnaces contains from 25% to 35% of this gas.

Liesegang (*Klin. Woch.,* 1928, v. 7, pp. 463-5) regards the presence of carbon monoxid in the atmosphere as having a pronounced effect on city dwellers. He cites the estimate of a daily total of 124,000 cubic meters of carbon monoxid produced by motor cars in the city of Berlin. Studies in 1926 estimated that motor vehicles at 42nd Street and Fifth Avenue in New York City discharged 30,000 cubic feet of carbon monoxid in a day.

The present percentage (from 7 to 14 per cent) of carbon monoxid in automobile exhaust gases is unnecessarily high. A high content of this gas represents a heavy sacrifice of miles per gallon for the sake of power and ease in starting a cold motor. Ample power may be had from any machine from a CO content of but 3 per cent by volume of the exhaust gases, and the present average content of over 7 per cent is wasteful.

Kinnicut and Sanford state that "air containing 0.3% of carbon monoxid causes death, 0.2% very dangerous symptoms, and that mice will quickly show the effects of the gas when the air contains only 0.005%. It produces headache, vertigo, malaise, muscular weakness, nausea, and vomiting and finally drowsiness, loss of consciousness, and death. Continued breathing of carbon monoxid gas causes severe anemia and its sequelæ."

Human blood has such an affinity for carbon monoxid

that it is taken into the circulation when the atmosphere contains no more than .004% or 1/25,000 part (Fodor). The fatal effects often produced by this gas are due to the fact that hemoglobin has an affinity for carbon monoxid and the compound formed—carboxyhemoglobin—is much more stable than oxyhemoglobin. If any considerable quantity of carbon monoxid is present in the air the hemoglobin will be almost completely charged with carboxyhemoglobin and asphyxia will result (Haliburton).

The studies for the Public Health Committee of the New York Academy of Medicine by Professor Yandell Henderson show that under certain atmospheric conditions, when little breeze is stirring and traffic is heavy, the carbon monoxid content of the street air in New York City reaches a point where prolonged and continuous exposure to it may have deleterious effects.

*Carbon dioxid.* According to Tobold, carbon dioxid in a proportion of 1:10 acts as a poison causing headache and shortness of breath; 30% may cause death. Schaffer states that in London 100,000 tons of carbon dioxid are poured into the air as smoke each day. Coullard believes that a smoky atmosphere is poisonous because of the large quantity of carbon dioxid rather than because of a deficiency of oxygen.

Renk says, "Normal air contains about .03% while city air contains .03% to .05%. This is not sufficient to prove a menace to health, yet small amounts of excess carbon dioxid inhaled for long periods of time would, within limits, tend to have the effects somewhat similar to those produced by large amounts breathed for a short period of time"—namely, accumulation of carbon dioxid in the blood, abatement of oxidation within the organs, lowering of body temperature, loss of reflex transmission to the limbs, to the eyes, and finally paralysis of the respiratory center and death.

4. *Chlorine and Nitrogen Gases.* These gases probably play a minor rôle in the effect of smoke upon health. They

occur mainly in the smoke of industrial centers. Coullard believes that chlorine fumes, while slightly vitiating, do not cause serious disorders except through prolonged inhalation in which case they might light up a tuberculous process.

Nitrogen vapors act, according to Coullard, "(1) by powerfully irritating the bronchi and the small pulmonary vessels to the point of producing centers of apoplexy and (2) by producing a special impoverishment of the blood."

## Instruments and Methods for Investigating Air Pollution.

*Capnometer.* From the beginning of the Mellon Institute's Air Pollution Investigation (L. W. Bass, *Science,* 70: 186, August 23, 1929), it was recognized that the photoelectric cell would play an important part in the determination of the amount of atmospheric contamination and its distribution outward and upward from sources. Sampling devices ordinarily enable one to estimate the content of solids in a small volume of air at a given time and place, or the total amount at a given place over a period of time. It was desirable, however, to have a continuous record, not only of the amount of pollution, but also of the effects of atmospheric conditions upon the distribution of solids after their emission from stacks or other sources.

With the helpful coöperation of members of the staff of the Westinghouse Research Laboratories, experiments were made first for work at short range, and in consequence a combination has been developed that may be used at night or in the daytime. It consists essentially of a source of light with a modulator, a receiver and amplifier, tuned, and an indicator or recorder, calibrated. It differs from "smoke indicators" in that it need not be attached to a smokepipe or stack and also in that it operates independently of any influence from daylight or artificial light other than that from the controlled source.

At the suggestion of W. A. Hamor, Assistant Director,

Mellon Institute, the apparatus has been named the capnometer (Greek *kapnos,* smoke, and *metron,* measure), for its purpose is to measure smoke—capnometry.

From the results of the work done in the laboratory the apparatus should be very helpful in securing data concerning the influence of furnace and firing conditions, precipitation, wind velocities, etc., upon the density due to pollution of the atmosphere. (From *Science,* March 28, 1930, vol. 71, No. 1839, pages 344-345).

*Soot Fall Survey.* Samples for this purpose are collected in jars or cans approximately four inches in diameter by ten inches high. These vessels are placed at various stations and changed monthly. The containers are cleansed and a small volume of distilled water is poured in to avoid loss of precipitate through the action of wind. Samples are analyzed to determine percentages of tar, and combustibles other than tar and ash.

*Determination of Intensity of Daylight.*

This can be determined by its effect in decomposing oxalic acid. Meller reports:

In 1912-1913 in Pittsburgh the intensity of daylight was determined by its effect in decomposing oxalic acid, thus: (a) This decomposition, on days when the presence of smoke or fog was recorded, was 75 per cent of what it was on days having practically the same number of hours of sunshine without the presence of fog or smoke in appreciable quantities. (b) A decrease of 39 per cent in the limit of visibility was accompanied by a decrease of 24 per cent in the decomposition of oxalic acid. (c) In the absence of smoke and fog there seemed to be little connection between the percentage of decomposition of oxalic acid and the limit of visibility. (d) There was an increase of acid decomposition with increase in the hours of sunshine.

*Screening Effect of Soot.*

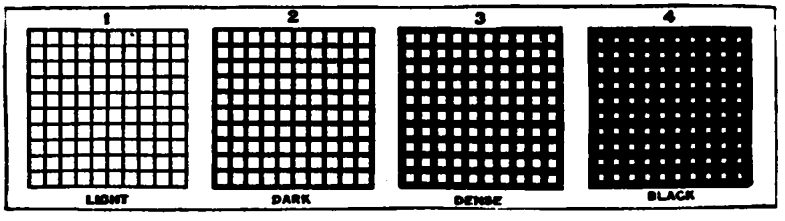
The accumulation of soot on skylights when exposed for a certain time interferes with the transmission of light. This

loss of light can be measured photometrically. In the smoky zone in Pittsburgh this was 80 per cent compared with about 40 per cent in one of the less smoky suburbs.

*Measurement of Solar Radiations.* This can be determined by an instrument called a spectograph. The spectograph is used for standardizing other instruments and for taking photographs of the solar spectrum.

*Solid Matter in Suspension.* This is sampled by the Owens Jet Dust Counter. The solid particles are precipitated on glass and the glass is then mounted on a slide for microscopic study. The number of particles are counted and the sizes are measured.

*Density of Smoke.* The density of smoke is measured by the Ringlemann Chart.




THE RINGLEMANN CHART USED IN PITTSBURGH

Place the chart on a line with a stack a sufficient distance from the eye to cause the lines to merge. Compare with the density of smoke under observation; if equal to or greater than 3, the smoke is a violation of the city ordinance and the operator is liable to penalty.

(Reprinted by permission from the May 1930 issue, *Scientific American*)

*Determination of Carbon Monoxid.* Carbon monoxid gas in the atmosphere is determined by the use of iodine pentoxid.

## Effects of Air Pollution on General Health

The Chief Medical Officer of the Ministry of Health of England, in his annual report on the state of the public health for the year 1927, writes:

"The recognition of the dependency of health on sunlight

is part of the inherited experience of mankind and does not call for mathematical demonstration. We are, however, now gaining more exact knowledge of the nature of this relationship and the conditions which influence it. The beneficial effects of exposure to the sun's rays have been demonstrated, for example, in such diseases as surgical tuberculosis and rickets, and the result is seen not only in the direct effect on the obvious disease, but in a general stimulation of body growth. The importance of sunlight to healthy growth is increasingly realized and the rearing of healthy children requires that they should not be deprived of what is so essential to their well-being."

Sunshine is an important biodynamic agent. It promotes anabolism, transpiration, and respiration, and increases the percentage of hemoglobin. The blue and ultraviolet rays of sunshine exert a bactericidal effect on pathogenic bacteria, and a tonic, vitalizing influence on the feelings. Moreover, colorless daylight is superior for visual efficiency and eye health.

Dark clouds have a depressing, devitalizing effect.

Humidity increases the solid, poisonous, bacterial contents of the air, aggravates various pathological conditions of the body, reduces the sensitivity of some sense organs, and depletes the vital potential. Fogs, in addition, increase the inaccuracy of mental work, the prevalence of diseases, and augment the death rate.

Clear, dry days are anabolic in character and thus produce a superabundance of energy.

Liefman concludes that darkening of the atmosphere of our cities is injurious to health in three ways: (1) An exciting impulse which influences our disposition is weakened and the energy of metabolism, especially as it concerns respiration, is diminished. (2) The illumination and warming of the earth, the water and the air within the precincts of our great cities is diminished and in this way a series of hygienically important processes is in-

fluenced or depressed. (3) The chemical and bactericidal effect of the sun's rays is decreased and thus bacteria, especially the pathogenic ones, are permitted to thrive. (*Mellon Inst. Bull.*, No. 9.)

According to Sir William Ramsay, "Smoke is harmful by its power to absorb light directly and by its effect in the formation of clouds and fogs which are peculiarly fitted to absorb the blue, the violet and ultra-violet rays, these being the rays that are especially germicidal. Diminution of sunshine causes an increase of bacteria in the atmosphere." He also believes that sunshine has a direct influence on the human skin as well as upon the mental state.

### Vision and Illumination and Ultra-Violet Rays

Cutting off sunshine and sky-shine (clouds reflect light) makes it necessary to use artificial light with its detrimental effect on vision.

Smoke acts as a curtain and cuts off the sun's direct rays, ultra-violet rays which are necessary for the healthy development not only of plants but of human beings. Rickets, anemia, and tuberculosis are likely to develop in children who are deprived of sunlight.

Doctor Henry F. Vaughan and Doctor Meader report that their "studies on sunlight have indicated that the rays at Northville, about twenty-five miles from the center of Detroit, contain about four times as much ultra-violet as do the rays in the city. This is apparently due to smoke."

Sir John Robertson, C.M.G., Medical Officer of Health, Birmingham, in his Annual Report for 1926, dealt at length with the smoke nuisance and its effects, and said that the extent to which the products of combustion are in the air of any large city has three chief influences on the inhabitants of the district: "It is prejudical to health, it causes a great deal of unnecessary labour and cleansing, and it limits the growth of many plants, and, therefore, hinders what is beautiful or useful in town gardens."

By far the most important of these, he considers, is the fact that all smoke or dust in the air shuts out, in direct proportion to its amount, the ultra-violet rays, and prevents them from reaching the dwellers in the area. "The absence of these rays for the greater part of the day lowers vitality, and by so doing renders most people susceptible to ailments which they themselves would not associate with the absence of sunlight."

"This deleterious effect," his report continues, "is for the most part produced by the very light and minute particles of soot which are carried high up in the air, and form by their presence an effective barrier to the sun's rays. It is possible to demonstrate this even when with unaided eyes the sun looks clear over the city."

McCollum of Johns Hopkins has shown that the growth-producing factor, Vitamin A, and the anti-rachitic factor in cod liver oil are not the same and the latter has been designated Vitamin D. In the earliest experiments it was found that the effect was produced by irradiating the animal, and it was supposed that in irradiating it, the cholesterol of the skin was activated in such a way that on absorption it so affected the lining membrane of the gut that the phosphorus and calcium became easily assimilable. This assumption was almost true. But it has since been proved that it is a substance always associated with the cholesterol which can be activated, viz., ergosterol, and it is this substance which, in various forms and under many names is now added to all the anti-rachitic proprietary preparations prominent in the medical market today.

Rickets is generally considered a disease of childhood and its far-reaching effects are often forgotten. Gynecologists dread the difficult labor of the woman deformed by rickets. The pelvic outlet is small. Spontaneous delivery is impossible. Instruments are necessary. There is danger of the soft parts being torn and sepsis supervening. Some believe that when this disease is wiped out there will be a coincident reduction in the puerperal fever rates.

The loss of light due to smoke in New York City is the subject of a recent report by the United States Public Health Service (*Public Health Bulletin,* No. 197). The results of this study may be briefly summarized as follows:

Records of the total horizontal illumination were obtained throughout the year 1927 with photo-electric cells and recording poteniometers simultaneously at the Hudson Street Marine Hospital, at the lower end of Manhattan Island, N. Y., where the air was very smoky, and on Hoffman Island, in lower New York Bay, about nine miles farther south, where the air was comparatively free from smoke.

From these records the average hourly horizontal illumination has been calculated for each of these two places for each month of the year. The daily average for each month and the hourly average for the year have also been calculated for each place. Both the absolute and the relative loss of light from smoke at the Hudson Street Hospital have been determined from the records.

The highest average daily horizontal illumination at Hoffman Island occurred in June and the lowest in December. The greatest total loss of light at the Hudson Street Hospital was in July and the least in December.

The records showed a large relative loss of light due to smoke. In some cases the average hourly or daily percentage loss was greater than 50 per cent. The average percentage loss for the whole year was 16.6 for clear days, 34.6 for cloudy days, and 21.5 for all days. The percentage loss on cloudy days was therefore about twice as great as on clear days.

An analysis of the results shows that the loss of light depends, among other things, upon the altitude of the sun, upon the nature of the daylight, whether from a clear or cloudy sky, upon the relative humidity of the air, and upon the velocity of the wind.

The effect of the altitude of the sun upon the percentage

loss of light is shown clearly in the variation of the percentage loss with the hour of the day. The average percentage loss throughout the year was 30.2 at 8:30 a. m., 16.5 at 1:30 p. m., and 21.0 at 3:30 p. m.

The average monthly percentage losses showed no marked seasonal variation, but did show a marked relation to the average monthly relative humidities, the percentage losses usually increasing and decreasing with the relative humidities. For clear days the greatest average monthly percentage loss was 23.1 in November and the least was 12.1 in May, with corresponding average relative humidities of 64.6 and 39.0 per cent. For cloudy days these values were 52.7 in September and 23.6 in December, with corresponding average relative humidities of 99.4 and 85.9 per cent.

Other conditions being the same, the average percentage loss of light was greater for cloudy days, or cloudy hours, than for clear days or clear hours; the percentage loss being about 1.5 times as great for cloudy days as for clear days, for relative humidities between 40 and 80 per cent, and for wind velocities between 10.0 and 19.9 miles per hour.

For the same kind of sky, clear or cloudy, the average percentage loss of light increased with increase of relative humidity. For a clear sky the average percentage loss was twice as great for a relative humidity of 65 per cent as for 35 per cent. For a cloudy sky the increase was not as great.

Other conditions being the same, the percentage loss of light was found to decrease as the velocity of the wind increased.

The percentage loss of light was found to be largely independent of the pressure of the water vapor in the atmosphere and therefore of the absolute humidity.

## Respiratory Diseases

The inhalation of carbon particles, irritating fumes, and other atmospheric impurities irritate the mucous membrane of the nose and lower its resistance, thus rendering it liable to acute and chronic infections which may involve the ear. Irritation alone can produce congestion of the mucous membrane, secondary swelling of the turbinates, and vacuum frontal sinus headaches. Patients in whom the membranes are diseased and the ciliated epithelium destroyed have great difficulty in eliminating the irritating particles and are therefore more sensitive to atmospheric pollution. In addition to this there is no doubt that some patients can be sensitized to certain forms of air pollution with the usual allergic manifestations. According to Doctor Henning of Leipzig, enlargement of the tonsils is common in firemen because of the irritating effects of smoke. Redness and congestion of the pharynx and larynx and tendency to inflammation of these tissues are predisposed to by atmospheric pollution.

*Effect of Air Pollution on the Lungs.* Doctor H. Osborne (*Medical Officer,* 1928) says, "During periods of winter fog owing to certain barometric conditions and absence of wind, smoke cannot get away but accumulates in the lower air strata. As a consequence the proportion of impurity is enormously increased and the concentration of sulphuric acid in the air may be such as to cause irritation of the eyes, nose, and respiratory passages. It is a common experience of local medical practitioners to find their bronchitis patients dying in numbers during prolonged periods of winter fog." He concludes as follows: "I would like to invite attention to a very striking correlation which emerges from a comparison of health statistics for the year 1926 with previous years. The general death rate for the year (12.5 per 1,000 living) is the lowest ever recorded for Salford. The greatest reduction of mortality occurred in the great group of respiratory diseases and this fact associated with the occurrence of the prolonged coal dispute

and consequent relative purity of our atmosphere, is a matter of some significance."

H. K. Kugel, Acting Commissioner of Smoke Inspection, Cleveland, writes that the survey made by the Mellon Institute several years ago in Pittsburgh seemed to show that in certain parts of the city which were the smokiest, diseases of the respiratory tract were much more numerous. A similar survey was made a short time ago in Akron and apparently shows the same trend.

It is interesting to note that the annual death rate from pneumonia is greater than from all other infectious diseases combined. Smoke irritates the mucous membrane and predisposes to diseases of the respiratory tract, especially pneumonia.

Professor Sir Leonard Hill, M.B., F.R.S., in a lecture delivered at the Medical Officers of Health Conference, at Newcastle-on-Tyne, in June, 1929, said: "Respiratory diseases now cause 40 per cent to 50 per cent of the lost time in workshops and offices and produce a vast amount of lessened efficiency and suffering."

Taylor says, as a result of inhaling about 35 lbs. of air daily, dwellers in the industrial cities have lungs more or less similar to those of the coal miner, not pinkish in color like those of a child or one who tills the field, but blackened, both on the surface and in the depths, due to the deposit of carbon. The tarry matter and the less visible sulphur acids which are far more dangerous than the carbon, set up an irritation in the mucous lining of the windpipe and smaller tubes. Chronic catarrh supervenes. The mucous lining becomes rough and thickened, the surrounding tissues lose their elasticity and become leathery in texture. These changes produce symptoms of chronic bronchitis, symptoms resulting from persistent irritation, partial collapse of the lungs, and incomplete oxygenation of the blood.

Dr. W. A. Brend has examined the main factors which

might be held to account for a high rate of infantile mortality and finds that differences "neither in poverty, bad housing, insufficient feeding, defective sanitation, disease, industrial occupation of women, nor malnutrition of mothers can be regarded as adequate to explain the excessive and widespread difference between urban and rural rate of infant mortality." Dr. Stevenson believes that chances of survival differ but little at birth in town and in the country, but the noxious influences of the former soon come into play, and make themselves felt to an increasing extent as the first year of life progresses, and to a still greater extent in the second and third years.

Brend believes that the noxious influence is "a smoky and dusty atmosphere and that as a cause of infant mortality it transcends all other influences," and if one of the main effects of soot is to cause bronchitis and lower the resistance of the respiratory organs then his argument is borne out by such figures as these:

Roughly 1/12th or all the deaths in England and Wales are due to respiratory diseases. In Manchester the respiratory death rate is twice as great. For all rural England the infantile death rate for 1928 due to pneumonia and bronchitis was 8.8, for the county boroughs 16.27, and for Manchester 23.16.

Professor Sir Leonard Hill, M.B., F.R.S., in a lecture at the Royal Sanitary Institute Congress at Bournemouth in 1922, said:

"Men live long who work in the clean open air of the fields: thus the expectation of life of females at birth in Westmoreland is 61, in Middlesborough 46 years. This is not merely a matter of greater infant mortality, for at age 15 the difference is 5½ years. Similarly for young adult females, Surry County has an advantage of nine years over smoky industrial Oldham, while the urban mortality per 1,000 living on the whole for males is one-third greater than the rural mortality—a proportion which has not changed in the last 50 years, although the mortality has

been generally lowered. This difference is very striking considering the good water supply, drainage and cleaning of the cities and the higher wages earned by city workers. . . ."

"In this country tuberculosis still kills and maims each year almost as many civilians as the great war did of our soldiers. In Japan there is now happening just what happened in England during the rise of industry at the beginning of the last century. Some 210,000 fresh girls are coming annually into the cotton mills from the country districts, while some 80,000 girls in the mills are annually discharged for sickness, and no less than 70 per cent of all their deaths is due to tuberculosis."

Seltman concludes that a deposit of coal in the lungs, as soon as it reaches a certain degree, diminishes the gaseous exchange by decreasing the breathing surface, checks the formation of blood, and so causes anemia and dyspnea. Vital statistics afford the most readily available standard of comparison. Dr. Louis Ascher concludes from his statistical studies, "The increase in the mortality of acute lung diseases must be the result of some harmful factor which, it is true, is found in agricultural communities, but with a much higher increase in industrial centers. This factor is not limited to the places of industrial work but is also found in the homes, as proved by the mortality tables for infants and old people. The cause of this increase can only be the smoke of the coal fires."

Trudeau's experiments on animals are considered by some authorities as evidence of the importance of sunlight in the cure of tuberculosis.

Trudeau says (*An Autobiography of Edward L. Trudeau, M.D.*) "Lot 1, of five rabbits, were inoculated with pure cultures and put under the best surroundings of light, food and air attainable.

Lot 2, of five rabbits, inoculated at the same time and in the same way, were put under the worst conditions of environment I could devise.

Lot 3, of five rabbits were put under similar bad conditions without being inoculated.

Lot 1, I turned loose on a little island in front of my camp at Paul Smith's, where they ran wild all summer in the fresh air and sunshine, and were provided with abundant food. Lot 2 and Lot 3 were put in a dark, damp place where the air was bad, confined in a small box and fed insufficiently. The results showed that of the rabbits allowed to run wild under good conditions, all, with one exception, recovered. Of Lot 2, the same as Lot 1, but put in unfavorable surroundings, four rabbits died within three months and the organs showed extensive tuberculosis. Lot 3, uninoculated animals, were then killed, and though emaciated, they showed no tuberculous disease.

This showed me conclusively that bad surroundings of themselves could not produce tuberculosis, and that when once the germs had gained entrance to the body the course of the disease was greatly influenced by a favorable or an unfavorable environment."

### Effect of Air Pollution on the Eye

Solid and vaporous ingredients of smoke-begrimed air irritate the sensitive membranes of the eye, and aggravate or cause inflammatory conditions, increasing susceptibility of the tissues to conjunctivitis. The functional efficiency of the eye may also be more or less disabled by the constant irritation of solid particles.

That smoke materially decreases the limits of visibility is evident when we learn that these limits vary with the number of dust particles in the air. For example, 1000 particles per cubic centimeter render large objects like mountains invisible at a distance of 100 miles; 100,000 particles render them invisible 1 mile away, and 1,000,000 particles 1/10 of a mile distant (Aitken).

The optical value of *good daylight* can hardly be overestimated. Daylight is relatively colorless because it contains both chromatic and achromatic light. A bright

colorless illumination is best from the standpoint of visual efficiency and health. It is less fatiguing than colored light or than intense or dull artificial light. Electric lights never quite replace daylight and are often too intense because of the proximity of the light or because the rays are thrown directly into the eyes or directly upon the object under observation. These conditions may lead to overstimulation of the sensitive layers of the retina. During the dark days which are common in manufacturing cities lights must be kept burning in the homes, schools, shops, and factories all day. This fact has been determined by Blair for the Pittsburgh schools. Even on clear days the lights must be turned on very early in the evening. The intensity of artificial illumination does not always meet the requirements of visual health. Worse still is the condition of those who, through financial limitations, must work in the dark gloom of smoky days without the aid of artificial light.

J. E. Wallin (*Optical Illusions of Reversible Perspective,* 1905) has shown in a special experiment on the visual estimation of distances that bright objects are judged to be nearer the observer than similar black objects when placed at the same distance. If this is true, anything on which the eyes must be fixated in darkened illumination will be imperfectly envisaged. To overcome this optical handicap, there is a strong tendency to move the object too near the eyes. If done repeatedly this entails a severe strain on the muscles of accommodation, causing increased muscular fatigue, which may result in muscular imbalance. On the other hand, by illuminating an object with good daylight it will be made to appear nearer to the eye. The result is that objects will actually be held at a greater distance and distant objects will be seen without eyestrain.

## Psychological Aspects of Air Pollution

The psychological effects of smoke are direct and indirect (Mellon Institute of Industrial Research and School of Specific Industries, *Smoke Investigation Bulletin,* No.

3). The indirect effects result from bodily changes produced by smoke or smoke-produced weather states, while the direct effects are due to the influences of the mind's own states upon its subsequent thoughts, disposition, and conduct. Smoke diminishes the potential reserve, working capacity, and well-being of the individual, increases fatigue, irritability and restlessness, whereas sunshine exerts an exuberant influence on the feelings, thus producing a superabundance of energy.

Dark clouds have a depressing, devitalizing effect. They may cause fear in children, and reduce working efficiency.

Our knowledge of the psychological reactions to atmospheric smoke pollution should be increased by systematic research using the questionnaire method and the experimental method with controlled subjects, controlled apparatus, and controlled smoke rooms.

## Effect of Air Pollution on Climate and Health

### *Fogs.*

Meller says, "The presence of sulphur acids resulting from combustion of fuel is believed to increase the probability of the formation and maintenance of fog in two ways. (1) In the presence of sunshine, nuclei are formed which have such an affinity for water that condensation sets in at temperatures higher than the saturation temperature. (2) Chemical affinity soon arrests the process of differentiation referred to, so that the fog particles maintain a small size and may be supported in the atmosphere for a long period."

Measurements made at the Mellon Institute showed that the weight of solids per 1000 cubic feet of air was twice as great in smoky atmosphere as in clear air.

Aitken says, (*Transactions of the Royal Society of Edinburgh,* v. 30, p. 337-368, 1883) "On account of the affinity between dust particles and vapor, each dust particle tends to take the same amount of vapor. This tends to equality in

the size of cloud particles and tends to prevent formation of larger drops by collision and union of cloud particles. As a result, the condensed vapor cloud instead of falling in minute parts as rain, tends to fall as a whole, the air becomes so loaded with the water held in the mechanical suspension that it is dragged downwards by its weight, causing fogs."

Brodie's data, with discussion, (*Quarterly Journal of the Royal Meteorological Society,* v. 31, p. 15-28) show steady decrease of fog since 1890. He thinks the result is largely due to substitution of gas for coal fuel.

Russel says (*Nature,* v. 39, p. 34-36) (Abstract of address delivered March 1, 1888, under the auspices of the Smoke Abatement Institution): "If London were to cease using fuel in the solid form, it would be as free from fog as the surrounding country." He discusses the economic disadvantage and the "moral reaction" of smoke and fog.

The following is an extract from Dr. René Sand's letter to Dr. E. H. L. Corwin, January 26th, 1931, in regard to the fog in the Meuse Valley: "The question of the 'deadly fog' in the Meuse Valley is in the hands of a committee. Many young and perfectly healthy people have died from it, and there is not the slightest doubt that some fumes (fluorhydric acid or sulphur dioxid), which are thrown daily in great quantities into the atmosphere by local factories, have been brought down near the soil and have accumulated through a very rare combination of atmospheric circumstances such as absolute quietness of the air, persistent and dense fog. It has always been a matter of surprise to me that factories are permitted to pollute the streams and the atmosphere without practically any check. One knows that in a radius of several miles around certain factories, trees wither and grass does not grow. When motoring through certain parts of the Meuse Valley, one is often half choked by poisonous fumes. Still we leave it at that, although as you know, devices have been found which would not even be very costly, as they permit the recovery of certain valuable chemical substances. The present sit-

uation is one of the worst examples of stupidity and neglect."

### Effect of Air Pollution on Vegetation and Secondarily on Health

Delepine says, "The large amount of arsenic in soot causes a marked arsenical contamination of the air in Manchester and may account for the bad effect of air on vegetation."

Meller believes that the injury done to vegetation by the soot in smoke is probably due chiefly to the accompanying ash, tar, and gases. Fumes containing sulphur dioxid and sulphur trioxid do considerable injury to vegetation. It is also known that certain of the hydrocarbon gases, carbon monoxid, hydrogen sulphid, and carbon disulphid are injurious to plants.

Soot is poisonous to vegetation as evidenced by external appearance, and also by internal appearance as shown by the size of the annular rings and by lesions in the leaves.

Professor F. E. Wynne, Medical Officer of Health for Sheffield, in a paper read at Lancaster in March, 1929, said: "The damage done by the deposition of soot can be more accurately measured in the case of vegetable life than animal life, and this has been done by Dr. A. E. Rushton of Leeds University. In one of his experiments, hollyhocks from the parent stock were grown in tubs of identical soil in different parts of the city. In the most polluted part of the industrial area, during the second year of the experiment, only one plant survived. It grew to a height of nine inches and failed to flower. In a comparatively smokeless area, some miles north of the city, a growth of eight feet was obtained with full flowering. The damage caused by soot therefore begins with vegetation and its consequent deterioration of our milk and meat supplies."

Professor Sir Leonard Hill (1922) states: "The choking of the leaves by tarry matter and the sulphur acids in

the smoke destroys vegetation and lessens the pleasure and health derived from the cultivation of gardens and the use and enjoyment of public parks. Radishes and lettuces grown at stages between the center and the suburbs of Leeds show enormous increase in size concurrently with the great distance between the producing ground and the city. The destruction of vegetation is of very great importance to health, not only from the æsthetic side but from the fact that fresh green foods and the milk of cows fed on such are protective foods containing vitamins essential for health, growth and breeding. The want of these is one of the great causes of malnutrition, disease and infertility in our big cities."

*Prevention of Air Pollution.*

Prevention is the only cure. This is primarily an engineering problem and concerns the Department of Health. The laws seem to be sufficient in number and probably are sufficiently drastic in the present state of our knowledge. Complete realization of the importance of air pollution to health and aroused public opinion will undoubtedly strengthen the position of our courts in dealing with this important problem.

## Summary and Conclusions.

1. There is an air pollution problem in New York City and other cities, which is a serious menace to health.

2. Although sanitation has progressed in many ways, the important problem of air pollution is still inadequately controlled.

3. The main sources of air pollution are locomotives, chimneys, boats, and automobiles.

4. Legislative and remedial measures at the present time are concerned with visible smoke alone, but the invisible products of combustion, sulphuric acid, sulphur dioxid, arsenic, carbon monoxid, carbon dioxid, and other poisons are a serious menace to health.

5. Instruments, apparatus, and methods are available for the detection and analysis of air pollution.

6. That air pollution exists in New York City is shown by the fact that deposits in New York in 1930 averaged 3.97 tons per square mile per month. The United States Public Health Records showed a large relative loss of light and healthgiving rays in New York City in 1927 and the presence of soot was a contributing factor. In some cases the average hourly or daily loss was greater than 50 per cent and the average daily loss for the year was 21.5 per cent. Studies of the carbon monoxid content of the air in New York City streets by Yandell Henderson showed that the amount of this poisonous gas was sufficient at times to produce deleterious effects.

7. Inhalation of carbon particles and irritating fumes lower the resistance of the nasal mucous membrane, rendering it susceptible to acute and chronic infections which may involve the ear. Enlargement of the tonsils, redness and congestion of the pharynx and larynx have also been ascribed to atmospheric pollution. Smoke likewise irritates the membranes of the entire respiratory tract, predisposing to pneumonia, and emphysema. Certain types of air pollution may sensitize the individual and produce allergic manifestations.

8. According to Oliver, "something is present in soot which irritates the skin and leads to cancer." This substance is now thought to be tar and may be a possible factor in the causation of cancer of the lung, the incidence of which is apparently increasing.

9. The sensitive membranes of the eye are inflamed by gases and particles of carbon, thus increasing the liability to conjunctivitis. Artificial light, necessary because of the smoke laden atmosphere, may be so intense as to overstimulate the sensitive layers of the retina, and low artificial and daylight illumination may cause eyestrain.

10. Smoke diminishes the potential reserve, working capacity, and well-being of the individual, and increases

fatigue and irritability, whereas sunshine exerts an exuberant influence on the feelings.

11. Although soot has a bactericidal action (Holman, W. K., *Am. Journal Public Health,* vol. 3, No. 11), smoky and humid weather conditions increase the bacterial content of the air (Russel, F. A. R., *Smithsonian Report,* 1895) and fogs increase the prevalence of disease. René Sand says that many young and healthy people died from the deadly fog in the Meuse Valley, due to fumes from local factories (fluorhydric acid or sulphur dioxid) which accumulated near the ground through a rare combination of atmospheric circumstances.

12. Vegetation is injured by smoke, as evidenced by experiments with plants grown in identical soil in smokeless and smoke-polluted districts.

13. That air pollution has a definite effect in increasing the incidence and death rate from tuberculosis is borne out by the classical experiments of Doctor Trudeau on animals; the accepted bactericidal action of sunlight; the healing reaction exhibited by extra-pulmonary tuberculous lesions when treated by the ultra-violet rays of the sun, and finally the low tuberculosis death rate of the states in which the population is largely rural as compared with the eastern industrial states.

14. The offensive odor of the exhaust smoke of automobiles, and of burning garbage and refuse, is not only a source of annoyance, but the odor may be so disagreeable as to disturb sleep.

15. Prevention of air pollution is a public health and engineering problem; the law is sufficiently comprehensive in the present state of our knowledge, but it should be strengthened by aroused public opinion and by courageous court action.

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